

chip

Integrated circuit. Chips are squares or rectangles that measure approximately from 1/16th to 5/8th of an inch on a side. They are about 1/30th of an inch thick, although only the top 1/1000th of an inch holds the actual circuits. Chips contain from a few dozen to several million electronic components (transistors, resistors, etc.). The terms chip, integrated circuit and microelectronic are synonymous.

TYPES OF CHIPS BY FUNCTION

Logic Chip

A single chip can perform some or all of the functions of a processor. A microprocessor is an entire processor on a single chip. Desktop and portable computers use one or more microprocessors while larger computers may employ several types of microprocessors as well as hundreds or thousands of specialized logic chips.

Memory Chip

Random access memory (RAM) chips contain from a couple of hundred thousand to several million storage cells (bits). They are the computer's working storage and require constant power to keep their bits charged. Firmware chips, such as ROMs, PROMs, EPROMs, and EEPROMs are permanent memory chips that hold their content without power.

Computer on a Chip

A single chip can contain the processor, RAM, ROM, I/O control unit, and a timing clock. It is used in myriads of consumer and industrial products.

Analog/Digital Converter

A single chip can perform the conversion between analog and digital signals, for example, a codec in a telephone.

Special Purpose Chip

Chips used in low-cost consumer items (watches, calculators, etc.) as well as higher-cost products (video games, automobile control, etc.) may be designed from scratch to obtain economical and

effective performance. Today's ASIC chips can be quickly created for any special purpose.

Logic Array and Gate Array

These chips contain logic gates which have not been tied together. A final set of steps applies the top metal layer onto the chip stringing the logic gates together into the pattern required by the customer. This method eliminates much of the design and fabrication time for producing a chip.

Bit Slice Processor

Bit slice chips contain elementary electronic circuits that serve as building blocks for the computer architect. They are used to custom-build a processor for specialized purposes.

HOW THE CHIP CAME ABOUT

Revolution

In late 1947, the semiconductor industry was born at AT&T's Bell Labs with the invention of the transistor by John Bardeen, Walter Brattain and William Shockley. The transistor, fabricated from solid materials that could change their electrical conductivity, would eventually replace all the bulky, hot, glass vacuum tubes used as electronic amplifiers in radio and TV and as on/off switches in computers. By the late 1950s, the giant first-generation computers were giving way to smaller, faster and more reliable transistorized machines.

Evolution

The original transistors were discrete components; each one was soldered onto a circuit board to connect to other individual transistors, resistors and diodes. Since hundreds of transistors were made on one round silicon wafer and cut apart only to be reconnected again, the idea of building them in the required pattern to begin with was obvious. In the late 1950s, Jack Kilby of TI and Robert Noyce of Fairchild Semiconductor created the integrated circuit, a set of interconnected transistors and resistors on a single chip.

Since then, the number of transistors that have been put onto a single chip has increased exponentially, from a handful in the early 1960s to millions by the late 1980s. Today, a million

transistors take up no more space than the first transistor.

A byproduct of miniaturization is speed. The shorter the distance a pulse travels, the faster it gets there. The smaller the components making up the transistor, the faster the transistor switches. Switch times of transistors are measured in billionths and trillionths of a second. In fact, a Josephson junction transistor has been able to switch in 50 quadrillionths of a second.

Logic and Memory

In first- and second-generation computers, internal main memory was made of such materials as tubes filled with liquid mercury, magnetic drums and magnetic cores. As integrated circuits began to flourish in the 1960s, design breakthroughs allowed memories to also be made of semiconductor materials. Thus, logic circuits, the "brains" of the computer, and memory circuits, its internal workspace, were moving along the same miniaturization path.

By the end of the 1970s, it was possible to put a processor, working memory (RAM), permanent memory (ROM), a control unit for handling input and output and a timing clock on the same chip.

Within 25 years, the transistor on a chip grew into the computer on a chip. When the awesome UNIVAC I, which you could literally walk into, was introduced in 1951, who would have believed that the equivalent electronics would later be built into a child's stuffed bear.

More Evolution

Just as integrated circuits eliminated cutting apart the transistors only to be reconnected again, eventually wafer scale integration will eliminate cutting apart whole chips only to be reconnected again. In time, instead of adding more circuits across the surface, the circuits will be built in overlapping layers. Within the next 10 to 15 years, it is conceivable that the electronics in today's multi-million-dollar supercomputer can be built within a cube one inch square!

THE MAKING OF A CHIP

Computer circuits are pathways carrying electrical

pulses from one point to another. The pulses flow through on/off switches, called transistors, which open or close when electrically activated. The current flowing through one switch effects the opening or closing of another and so on. Small clusters of transistors form logic gates, which are the building blocks behind all this magic, and a specific combination of logic gates make up a circuit.

From Logic to Plumbing

Today, the majority of circuits being used have already been designed and reside in circuit libraries in a computer. A computer designer merely has to pick and choose ready-made modules (standard cells) from a menu. But they all had to be invented at one point, and new circuits still have to go through an elaborate process to convert logical patterns on paper into an equivalent maze of plumbing on the chip.

Computers help make computers. The logical design is entered into the computer and converted into transistors, diodes and resistors. Then the combination of electronic components is turned into a plumber's nightmare that is displayed for human inspection. After corrections have been made, the completed circuits are transferred to specialized machinery that create lithographic plates made out of glass, called photomasks. The photomasks are the actual size of the wafer and contain as many copies of the design of the chip as will fit on the wafer. The transistors are built by creating subterranean layers in the silicon, and a different photomask is created to isolate each layer to be worked on. With each layer, the same part of every transistor on every chip is constructed at the same time.

Chips Are Just Rocks

The base material of a chip is usually silicon, although materials such as sapphire and gallium arsenide are also used. Silicon is found in quartz rocks and is purified in a molten state. It is then chemically combined (doped) with other materials to alter its electrical properties. The result is a silicon crystal ingot from three to five inches in diameter that is either positively (p-type) or negatively charged (n-type). Wafers, about 1/30th of an inch thick, are cut from this "crystal salami."

Building the Layers

Circuit building starts out by adhering a layer of silicon dioxide insulation on the wafer's surface. The insulation is coated with film and exposed to light through the first photomask, hardening the film and insulation below it. The unhardened areas are etched away exposing the silicon base below. By shooting a gas under heat and pressure into the exposed silicon (diffusion), a sublayer with different electrical properties is created beneath the surface.

Through multiple stages of masking, etching, and diffusion, the sublayers on the chip are created. The final stage lays the top metal layer (usually aluminum), which interconnects the transistors to each other and to the outside world.

Each chip is tested on the wafer, and bad chips are marked for elimination. The chips are sliced out of the wafer, and the good ones are placed into packages (DIPs, SIMMs, SIPs, etc.). The chip is connected to the package with tiny wires, then sealed and tested as a complete unit.

Chip making is extremely precise. Operations are performed in a "clean room," since air particles can mix with the microscopic mixtures and easily render a chip worthless. Depending on the design complexity, more chips can fail than succeed.

The Future

In order to miniaturize elements of a transistor even further, the photomasks have to be made with x-rays or other beams which are narrower than light. Eventually, circuit patterns will be etched directly onto the chip, eliminating the entire photographic masking process.

During the 1990s, multi-million-transistor chips will be commonplace. However, when wafer scale integration becomes a reality, one wafer could hold a gigabyte of memory and a processor five times as large as the Pentium along with a quantum reduction in cost. If superconductor transistors take hold, there will be a gigantic leap in performance. Should both technologies arise at the same time, hold on to your hats!